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Camerolaite, $Cu_4Al_2[HSbO_4,SO_4](OH)_{10}(CO_3) \cdot 2H_2O$, a new mineral from Cap Garonne mine, Var, France

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With 2 figures and 3 tables in the text

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Abstract: Camerolaite, ideally $Cu_4Al_2[HSbO_4,SO_4](OH)_{10}(CO_3) \cdot 2H_2O$, occurs on a specimen found in the mine of Cap Garonne, Var, France. It is associated with parnauite, cyanotrichite, malachite in a quartz gangue. The crystals, blue-green in colour, form tufts, acicular and radiated-fibrous aggregates (0.5–2 mm). They are flattened on {100} and very elongated parallel to [010]. The observed form are {100} and {001}. Cleavages {100} and {001} are good. Crystals are transparent, with silky lustre and pale green streak; brittle with fibrous fracture. They are non fluorescent. A chemical analysis carried out by means of electron probe: CuO 40.56; Al_2O_3 14.54; Sb_2O_5 13.55; SO_3 4.75 and CO_2 6.26; H_2O 20.0 (by CHN); total 99.66 wt.%. The mineral is monoclinic, with a = 10.765(6), b = 2.903(2), c = 12.527(8) Å; β = 95.61(4)°; space group $P2_1$, or $P2_1/m$; V = 389.6(7) $Å^3$ and Z = 1. The density is 3.1(1) (measured), 2.96 g/cm^3 (calculated with M.W. = 695.4), 3.09 g/cm^3 (with idealized formula). The strongest lines in the X-ray powder diffraction pattern are [d Å, (hkl), I vis.]: 5.62, (1 0 −2), 50; 5.160, (1 0 2), 90; 4.276, (2 0 −2), 100; 3.565, (3 0 0), 40; 2.380, (0 1 3) (1 0 5) (4 0 2), 35; 2.326, (2 1 2), 35. Camerolaite is optically biaxial positive with 2V meas. = 77(3)°, 2V calc. = 75°; refractive indices at 590 nm are: α = 1.626(2), β = 1.646(2), γ = 1.682(2). Optical orientation: γ = b, $\alpha \perp$ {100}; dispersion r < v strong. The new mineral camerolaite is named for Mr. Michel Camerola.

Key words: Camerolaite, antimonate, new mineral, France (Cap Garonne).

Introduction

The sample containing camerolaite was collected by Mr. Michel Camerola in the old copper-lead mine of Cap Garonne, near Toulon, Var, France. Mineralization occurs in triassic sandstones and conglomerates. The new mineral is associated with parnauite, cyanotrichite and malachite in a quartz gangue. The mineralogy of Cap Garonne deposit was studied by Guillemin (1952) and Mari & Rostan (1986). We gave the name of camerolaite to honour Mr. Michel Camerola who is an eminent mineral collector. Both the mineral and

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the name have been approved by the IMA-Commission on New Minerals and Mineral Names, prior to publication. Holotype is preserved in the Mineralogy Department of the Natural History Museum, Geneva, Switzerland.

Physical and optical properties

Camerolaite forms tufts and radiating fibrous aggregates (0.5 – 2 mm) of acicular crystals (Fig. 1); these are slender and very thin (0.5 mm length and 0.01 mm width). Crystals are transparent, blue-green coloured, with silky lustre and pale-green streak. They are not fluorescent under U.V. Fracture is fibrous. Hardness could not been determined owing to the small size and brittleness of the crystals. Cleavages {100} and {001} are good. No twinning observed. Crystals are flattened on {100} and very lengthened parallel to [010]. Observed forms are {100} and {001} (Fig. 2). The mineral is soluble in HCl.

Camerolaite is optically biaxial positive with 2V meas. = 77(3)°, 2V calc. = 75°; refractive indices at 590 nm are: $\alpha = 1.626(2)$, $\beta = 1.646(2)$, $\gamma = 1.682(2)$. Optical orientation: $\gamma = b$, $\alpha \perp \{100\}$; dispersion $r < v$ strong. As crystals are extremely thin, it is impossible to measure angles $\alpha \wedge a$ and $\beta \wedge c$. Pleochroism: α = colorless, β = pale-green, γ = blue-green.

The density measured using heavy liquids is 3.1(1) g/cm³. Calculated density is 2.96 g/cm³ (with M.W. = 695.4) and 3.09 g/cm³ with idealized formula. Cal-

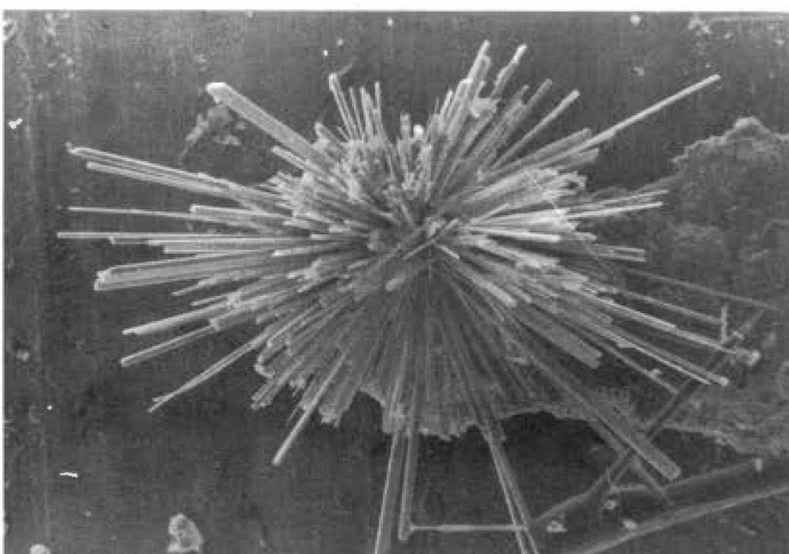

Fig. 1. Tuft of camerolaite (diam. 0.6 mm). (SEM photograph, Dr. J. Wuest, Nat. Hist. Museum, Geneva.)

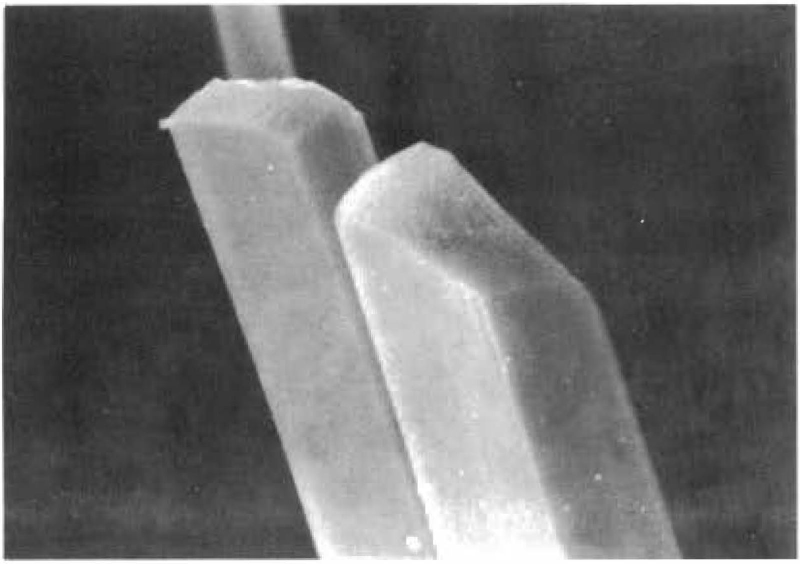

Fig. 2. Detail and morphology of a camerolaite crystal. The face on the left is (100); the face on the right is (001). The crystals are 0.01 mm in width. (SEM photograph, Dr. J. WUEST, Nat. Hist. Museum, Geneva.)

culation of the Gladstone-Dale relationship using constants given by MANDARINO (1981 a) gives an excellent compatibility: 1 - Kp/Kc = −0.020.

Chemical composition

Chemical composition was studied using microprobe. Qualitative investigations showed the presence of elements Cu, Al, Sb and S. Quantitative analysis using wavelength dispersive microprobe (CAMECA) was obtained using the following standards: chalcopyrite (Cu, S), aluminum (Al), tellurantimony (Sb).

Table 1. Chemical analysis of camerolaite.

	Range % weight of 8 analyses	Average % weight of 8 analyses	Standard deviation
CuO	39.37 – 41.88	40.56	0.9
Al_2O_3	13.81 – 15.41	14.54	0.5
Sb_2O_5	12.22 – 15.48	13.55	1.1
SO_3	4.08 – 5.25	4.75	0.4
CO_2		6.26	
H_2O		20.00	
Total		99.66	

Quantitative measurements were operated under following experimental conditions: 15 kV electron-beam accelerating voltage, 2.6 nanoamperes beam current, 6 microns diameter beam. The ranges of 8 analysis and their averages are given in Table 1. H_2O and CO_2 were determined with HERAEUS CHN analyser.

Table 2. X-ray powder diffraction data of camerolaite.

h k l	$d_{calc.}$	$d_{meas.}$	$I_{vis.}$
1 0 0	10.713	10.7	10
0 0 2	6.234	6.21	5
1 0 $\bar{2}$	5.633	5.62	50
1 0 2	5.173	5.160	90
2 0 $\bar{2}$	4.275	4.276	100
2 0 2	3.880	3.880	10
3 0 0	3.571	3.565	40
1 0 $\bar{4}$	3.074	3.076	10
3 0 2	2.976	2.977	10
1 0 4	2.917	2.905	<5
0 1 0	2.903		
1 1 0	2.802	2.798	5
4 0 0	2.678	2.675	20
4 0 $\bar{2}$	2.553	2.552	15
2 1 0	2.552		
2 1 $\bar{2}$	2.402	2.418	10
0 1 3	2.380	2.380	35
1 0 5	2.378		
4 0 2	2.378		
2 1 2	2.324	2.326	35
1 1 3	2.296	2.293	<5
2 1 $\bar{3}$	2.221	2.222	5
3 1 1	2.193	2.198	<5
5 0 0	2.143	2.137	30
4 0 $\bar{4}$	2.137		
2 1 3	2.131		
5 0 $\bar{2}$	2.090	2.080	20
1 0 $\bar{6}$	2.078		
0 0 6	2.078		
1 0 6	2.004	2.002	10
2 0 $\bar{6}$	2.004		
4 0 $\bar{5}$	1.921	1.918	30
4 1 $\bar{2}$	1.917		
5 0 $\bar{4}$	1.852	1.857	30
2 1 $\bar{5}$	1.827	1.818	5
5 1 $\bar{1}$	1.726	1.726	10
4 0 $\bar{6}$	1.725		
3 1 $\bar{5}$	1.725		
6 0 2	1.674	1.672	30

Empirical formula calculated on the basis of 19 oxygen atoms gives: $Cu_{3.56}Al_{1.99}Sb_{0.59}S_{0.41}C_{0.99}H_{15.51}O_{19.00}$. Simplified formula is: $Cu_4Al_2[HSbO_4, SO_4](OH)_{10}(CO_3) \cdot 2H_2O$. Idealized formula with Sb : S = 0.6 : 0.4 gives the following composition: CuO 43.90; Al_2O_3 14.07; Sb_2O_5 13.39; SO_3 4.42; CO_2 6.07; H_2O 18.15; total 100 %.

X-ray crystallography

Powder diagram was obtained from a 114.6 mm diameter Gandolfi camera, CuKα (Ni-filtered) radiation. Values of $d_{calc.}$ and $d_{obs.}$ are given in Table 2. A monocrystal was studied using a precession camera. We obtained a monoclinic unit-cell with the possible space group $P2_1$ or $P2_1/m$, the dimensions of which having been refined from powder diagram with least squares refinement method: a = 10.765(6), b = 2.903(2), c = 12.527(8) Å, β = 95.61(4)° and V = 389.6(7) Å^3. Z = 1 with idealized formula, $d_{calc.}$ = 3.09(1) g/cm^3; with M.W. = 695.4 (MANDARINO, 1981 b), $d_{calc.}$ = 2.96 g/cm^3. The a : b : c ratios calculated from the unit-cell parameters are 3.7082 : 1 : 4.3152.

Discussion and conclusion

This new mineral is crystallographically and chemically related to cyanotrichite and carbonate – cyanotrichite (Table 3). If we consider the case when Sb completely replaces S in cyanotrichite, we shall have $Cu_4Al_2(HSbO_4)(OH)_{12} \cdot 2H_2O$ or $Cu_4Al_2(SbO_3OH)(OH)_{12} \cdot 2H_2O$. It is highly unlikely that theoretical formula $Cu_4Al_2(SbO_4)(OH)_{11} \cdot 2H_2O$ might be applied to this mineral group because 12(OH) are well defined in their formula (Dana's System of Mineralogy). As for the $HSbO_4$ component, it may be written SbO_3OH which is an analogue of AsO_3OH that is present in many minerals. In short, camerolaite with the composition $Cu_4Al_2(SbO_3OH,SO_4)(OH)_{10}(CO_3) \cdot 2H_2O$, could be found in nature with an end member where Sb would completely replace S; the formula would be $Cu_4Al_2(SbO_3OH)(OH)_{10}(CO_3) \cdot 2H_2O$ or $Cu_4Al_2(SbO_3OH)(OH)_{12} \cdot 2H_2O$.

Table 3. Comparison of camerolaite with cyanotrichite and carbonate – cyanotrichite.

Cyanotrichite	Carbonate – cyanotrichite	Camerolaite
(JCPDS-11-131)	(JCPDS-16-365)	
$Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$	$Cu_4Al_2(CO_3,SO_4)(OH)_{12} \cdot 2H_2O$	$Cu_4Al_2(SbO_3OH,SO_4)(OH)_{10}(CO_3) \cdot 2H_2O$
acicular fibrous	acicular fibrous	acicular fibrous
dm = 2.85 g/cm^3	dm = 2.65 g/cm^3	dm = 3.1 g/cm^3
sky-blue, azure-blue	sky-blue, azure-blue	blue-green
α = 1.558, β = 1.617, γ = 1.655	α = 1.616, γ = 1.677	α = 1.626, β = 1.646, γ = 1.682
2Vγ = 82°	2Vγ = 55–60°	2Vγ = 77°
Orthorhombic	Isostructural with cyanotrichite	Monoclinic, $P2_1$ or $P2_1/m$
a = 10.16, b = 12.61, c = 2.90 Å		a = 10.765, b = 2.903, c = 12.527
Z = 1		β = 95.61 (4)°, Z = 1

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